ORIGINAL ARTICLE

Correlation between Skinfold Thickness and Total Daily Dose of Insulin in Patients with Type 2 Diabetes Mellitus in a Tertiary Hospital

Amilia Putri Larasati[1], Jongky Hendro Prajitno[2,3*], Bambang Purwanto[4]

[1]Faculty of Medicine, Universitas Airlangga Surabaya, Indonesia

[2]Department of Internal Medicine, Faculty of Medicine, Universitas Airlangga - Dr Soetomo General Academic Hospital, Surabaya, Indonesia

[3]Indonesian Association of Internal Medicine

[4]Department of Medical Physiology and Biochemistry, Faculty of Medicine, Universitas Airlangga, Surabaya, Indonesia

ABSTRACT

Introduction: Type 2 diabetes mellitus (T2DM) is a non-communicable disease with a high prevalence in Indonesia. T2DM is caused by insulin resistance and relative insulin deficiency. One of the therapy for T2DM is insulin administration which is injected into the subcutaneous tissue. The absorption of insulin in the subcutaneous tissue is influenced by many factors, one of which is the thickness of subcutaneous fat. This study aimed to determine the correlation between the skinfold thickness of T2DM patients with the total daily dose of insulin needed every day.

Methods: This was an observational analytic study using a cross-sectional design to analyze the correlation between subcutaneous fat thickness represented by skinfold thickness and the total daily dose of insulin of T2DM patients. Measurement of skinfold thickness was carried out on the triceps using a skinfold caliper. Data on the patient's total daily dose of insulin were obtained from medical records.

Results: A total of 53 patients were included in this study. The patient's mean triceps skinfold thickness was 26.29±8.72 mm. The mean total daily dose of insulin was 40.96±18.01 IU. The results of the Spearman Rank correlation test showed a significant correlation between skinfold thickness on the triceps and the patient's total daily dose of insulin ($p<0.05$).

Conclusion: The higher the skinfold thickness, the greater the dose of insulin needed by the patient.

Keywords: Type 2 diabetes mellitus; insulin total daily dose; skinfold thickness; subcutaneous fat

Correspondence: Jongky Hendro Prajitno
E-mail: dokjongky@yahoo.com

Article history: •Received 5 May 2023 •Revised 15 June 2023 •Accepted 3 July 2023 •Published 31 August 2023

INTRODUCTION

Diabetes mellitus has several different types, one of them is the type 2 diabetes mellitus (T2DM). Patients with T2DM suffer from insulin resistance and relative insulin deficiency (ADA, 2010). Type 2 diabetes mellitus (T2DM) is a non-communicable disease with a high prevalence in both the world and Indonesia. Based on International Diabetes Federation (IDF), Indonesia ranks 7th as the country with the highest diabetes prevalence in the world, which affects 10.7 million people, and predicted to raise to 16.6 million in 2045 (IDF, 2019).

The pharmacological therapy for controlling T2DM can be in the form of oral on injected medications. One of the types of injected medication is insulin. Insulin for T2DM is considered to be given if the glycaemic target (A1C <7%) is not achieved after the patient has received monotherapy or dual therapy for 3 months (ADA, 2019). The American Association of Clinical Endocrinologists (AACE) recommends initiation of long-acting basal insulin with a total daily dose (TDD) of 0.1 – 0.2 unit/kg for patients with A1C <8% or 0.2 – 0.3 unit/kg for patients with A1C > 8%, with titration every 2 – 3 days to achieve the glycaemic target. Initiation and titration of insulin in T2DM patients can be a challenge for primary healthcare providers resulting in delayed in insulin initiation (Chun et al., 2019). This delay significantly impacts the increased risk of developing microvascular complications of diabetes mellitus (Chun et al., 2019).

Insulin is injected into the subcutaneous tissue. The absorption rate of insulin can be varied depending on several factors, such as the fat thickness of the subcutaneous tissue where insulin is absorbed from. High subcutaneous fat may slow the absorption and change or delay the time-action profile of insulin and people with severe obesity may need a higher insulin daily dose and multiple split insulin injections to enhance its action and predictability (Morello, 2011). Subcutaneous fat thickness can be measured indirectly by measuring the skinfold thickness (Duren et al., 2008). The triceps is the most frequently chosen site for measuring skinfold thickness because it is easily accessible, reproducible, and can measure wide differences between people (Wang et al., 2006). Triceps skinfold thickness indicates peripheral subcutaneous fat (Eaton-Evans, 2012) and also correlates with BMI (body mass index) (Chavhan et al., 2020). Differences in skinfold thickness are associated with variability of insulin depot size, subcutaneous blood flow, and insulin absorption in diabetics (Gradel et al., 2018). This study aimed to determine the correlation between the

Available at https://e-journal.unair.ac.id/CIMRJ ; DOI: 10.20473/cimrj.v4i2.49154

skinfold thickness of T2DM patients with the total daily dose of insulin needed every day.

METHODS

This was an analytic observational study using a cross-sectional design. This study was conducted in the Endocrine outpatient clinic at Dr. Soetomo General Academic Hospital, Surabaya, Indonesia. The subjects of this research were recruited using purposive sampling method. The inclusion criteria for this research were T2DM patients who used insulin injections as their therapy, having A1C <8%, and did not get insulin dose titration. Whereas, the exclusion criteria were T2DM patients receiving additional therapy, either insulin or oral antidiabetic drugs (OAD), having a history of hospitalization in the last 3 months, and had more than 2 kg weight loss in the last 3 months. The patients who met the inclusion and exclusion criteria were then recruited as subjects for this research. All of the subjects' skinfold thickness on the triceps was measured using the Harpenden skinfold caliper two times and the average was recorded. The subjects' total daily dose of insulin and characteristics, such as age and sex, were obtained from the medical records. The correlation of skinfold thickness and the total daily dose of insulin then were analyzed using IBM SPSS Statistics ver. 25.

This research was approved by the Health Research Ethics Committee of Dr. Soetomo General Academic Hospital with Ethical Clearance number 0303/KEPK/XI/2021. All the subjects were given informed consent before agreeing to become the subject of this research.

RESULTS

The total number of patients who met the inclusion and exclusion criteria and were recruited from April to August 2022 was 53. The subjects' age and gender are shown in Table 1. The mean age of the subjects was 53.9±8.9 years, with the highest age group being 50-59 years and the lowest being 30-39 years. Sex distribution of the subject showed that the number of female patients was 27 people and the males was 26 people. The mean for the triceps skinfold thickness was 26.29 mm and it was higher in females than in males. For the insulin total daily dose, the mean was 40.96 IU, as shown in Table 2.

The correlation between triceps skinfold thickness and the total daily dose of insulin was determined using Spearman's Rank Correlation because the data distribution was not normal. The result was $p<0.05$, meaning there was a significant correlation between the two variables. The coefficient correlation value was $r=0.325$ which showed a moderate relationship, which can be seen in Table 3.

Table 1. Subject's characteristics

Characteristics	Total N = 53	Percentage (%)
Age (years)		
30 – 39	1	1.9%
40 – 49	16	30.2%
50 – 59	22	41.5%
60 – 69	11	20.8%
70 – 79	3	5.6%
Sex		
Female	27	50.94%
Male	26	49.06%

Table 2. Subject's triceps skinfold thickness and insulin total daily dose

	N	Min	Max	Mean	SD
Triceps Skinfold Thickness (mm)	53	8	47.25	26.29	8.72
Female	27	18	47.25	30.90	8.39
Male	26	8	33.5	21.50	6.17
Insulin Total Daily Dose (IU)	53	18	98.00	40.96	18.01

Table 3. Spearman's rank correlation test result

		Triceps Skinfold Thickness	Insulin Total Daily Dose
Triceps Skinfold Thickness	Correlation Coefficient	1.000	.325
	Sig. (2-tailed)	.	.018
	N	53	53
Insulin Total Daily Dose	Correlation Coefficient	.325*	1.000
	Sig. (2-tailed)	.018	.
	N	53	53

DISCUSSION

From the characteristics of the subjects, it was found that the age group ranging from 50–59 years was the highest among other age groups. This was also found in another study by Khan et al. (2020) who studied the global epidemiology of T2DM, where most T2DM patients aged 55-59 years. The number of female subjects in this study was higher than males, despite the slight difference. Data from Riskesdas (2018) from the Indonesian Ministry of Health also stated that in Indonesia, diabetes was found higher in females. A different result was found in another study by Khan et al. (2020) and Sun et al. (2022) that the prevalence of T2DM in females and males is rather equal. Tramunt et al. (2020) reported that the prevalence of T2DM was higher in males because they are more likely to be obese, have insulin resistance, and have hyperglycemia than in females.

The average triceps skinfold thickness results found in this study was 26.29±8.72 mm, with females having it higher than males. A higher triceps skinfold thickness in females was also found in other studies in Turkey and India (Selcuk et al., 2013; Chavhan and Chandrachood, 2020). This is possible because total body fat in females is higher than in males and it is mostly deposited in the subcutaneous area rather than the visceral (Khera et al., 2009; Pausova, 2014). Skinfold thickness is also affected by age. In the older population, fat distribution decreases in the subcutaneous tissue and increases in the visceral (Nguyen et al., 2021). As it was reported in a study by Dwimartutie et al., (2009), the triceps skinfold thickness interval in subjects aged more that 60 years was 4–32 mm, which is lower than that found in this study.

In this study, the total daily dose of insulin multiple daily injections in T2DM patients used every day was recorded, without differentiating the type of insulin used. The average total daily dose used by the patients in this study was 40.9±18.01 IU. Similar result was also found in another study in India, where the total daily dose of insulin used was 43.3±23.4 IU (Kesavadev et al., 2013). The similarity of these results may be caused by the similarity of diets in Indonesia and India, where the common carbohydrate consumed is rice. Carbohydrate consumption is one of the factors that affect the insulin doses needed (Nourizadeh-Sedaghati et al., 2016). In another study by Reznik et al. (2014) conducted multicentred in Canada, Europe, Israel, South Africa, and the United States, the

reported average total daily dose of insulin was 122±68 IU in T2DM patients with multiple daily injections. The high dose of insulin used compared to the results obtained in this study was due to the fact that the study subjects included were T2DM patients with uncontrolled blood glucose and insulin resistance, with an average total insulin dose of 1.1 IU/kg.

In this study, there was a significant correlation ($p < 0.05$) between triceps skinfold thickness and insulin total daily dose in T2DM patients at Dr. Soetomo General Academic Hospital with a moderate positive correlation ($r=0.325$). This correlation means that the thicker the subcutaneous fat or skinfolds, the higher the insulin dose needed per day. However, there are other factors that affect the insulin total daily dose besides the skinfold thickness.

The absorption of insulin from the subcutaneous tissue is affected by many factors. These factors create variability in the effects of insulin which will result in unpredictable therapeutic responses, inadequate glycaemic control, and an increased risk of hypoglycemia (Gradel et al., 2018). One example is insulin glargine, where the difference in the biological action of insulin is more influenced by its absorption in the subcutaneous tissue (Mudaliar et al., 2002).

In people with obesity, the high thickness of subcutaneous fat affects the reduced capillary density and reduces subcutaneous blood flow which causes slow absorption of insulin, which will also contribute to changes in the pharmacokinetics of insulin (Morello, 2011; Gradel et al., 2018). The results obtained in this study were consistent with those of Gradel et al. (2019) who conducted experiments on mice fed with high-fat and low-fat diets. In rats fed with high-fat diet, absorption of insulin Aspart after subcutaneous injection was slower than in rats fed with low-fat diet. This is caused by the smaller subcutaneous insulin depot after injection in mice fed with high-fat diet, where the smaller the injection depot, the slower the loss or absorption of insulin from the subcutaneous tissue. A study conducted by Hildebrandt and Vaag (1993) showed that skinfold thickness is directly proportional to the size of the CSII (continuous subcutaneous insulin infusion) insulin depot at steady-state. This suggests that insulin absorption is slower in patients who have higher skinfold thickness. Gagnon-Auger et al. (2010), who studied the pharmacokinetic differences of short-acting insulin analogs in obese T2DM patients, found that both the absorption and action of insulin lispro were greatly delayed at high doses (30 and 50 units). However, different results were found in the study of Clauson and Linde, (1995) which compared the absorption of rapid-acting insulin in obese and non-obese T2DM patients. In that study, no difference was found between absorption in obese and non-obese patients. This might happen because the average fat thickness of the study subjects was lower than this study.

In addition to obesity and subcutaneous fat thickness, subcutaneous insulin absorption is affected by other factors, such as injection site, temperature, physical activity, and differences in insulin types (Gradel et al., 2018). Various insulin injection sites have different absorption rates depending on the injection site. Insulin absorption is more rapid in the abdomen and deltoid than in the thighs and buttocks (Morello, 2011; Gradel et al., 2018).

Bitton et al. (2019) compared the effects of heating and cooling at the injection site of insulin glargine and found that warming had an effect on increasing insulin absorption. This is possible because an increase in temperature causes vasodilation. Vasodilation caused by an increase in temperature can occur due to the effects of a vasodilator the NO (nitric oxide). NO is produced from the conversion of L-arginine to L-citrulline and NO that is catalyzed by NOS (nitric oxide synthase) (Förstermann and Münzel, 2006). There are 3 isoforms of NOS, namely nNOS (neural NOS), iNOS (inducible NOS), and eNOS (endothelial NOS). Local warming triggers eNOS (Kellogg et al., 2008), while heat stress applied to the whole body (whole body heat stress) triggers nNOS to produce NO (Kellogg et al., 2008).

Physical activity and exercise accelerate insulin absorption subcutaneously (Gradel et al., 2018). Study by Berger et al. (1982) also found that massage at the site of insulin injection and exercise increased the rate of insulin absorption. Heinonen et al. (2012) reported that during exercise, the blood vessels in the subcutaneous tissue that are close to the contracting muscles will be vasodilated due to the influence of the heat generated by the muscles. Rhythmic muscle contractions that occur during exercise are one of the stimuli for increased shear stress on the arterial circulation (Casey et al., 2017). Shear stress itself is a tangential force of blood flowing on the surface of the vascular endothelium (Paszkowiak et al., 2003). Shear stress induced by muscle contraction can increase the phosphorylation of eNOS, which in turn increases NO bioavailability (Casey et al. , 2017).

CONCLUSION

Subcutaneous fat thickness, as measured by skinfold thickness, is one of many factors that affect insulin absorption from the subcutaneous tissue. Therefore, more attention is needed to these factors in administering insulin doses to T2DM patients in order to avoid unwanted risks, such as the risk of hypoglycemia and not achieving the desired glycemic target.

ACKNOWLEDGEMENT

The authors would like to thank all the patients that have agreed to be the subject of this study and the doctors and staff at the Endocrinology clinic at Dr. Soetomo General Academic Hospital.

CONFLICT OF INTEREST

The authors declare there is no conflict of interest.

ETHICS CONSIDERATION

This research was approved by the Ethical Committee for Health Research of Dr. Soetomo General Hospital with ethical clearance number 0303/KEPK/XI/2021.

FUNDING DISCLOSURE

This research was self funded.

AUTHOR CONTRIBUTION

All authors have contributed to all process in this research, including preparation, data collection and analysis, drafting and approval for publication of this manuscript.

REFERENCES

American Association of Clinical Endocrinologist. (2020) Initiating and Intensifying Insulin Therapy in Patients With Type 2 Diabetes CDC. 2020. HIV and MEN. Available at https://www.cdc.gov/hiv/group/gender/men/index.html. Accessed 4 January 2022.

American Diabetes Association (2010) 'Diagnosis and classification of diabetes mellitus', Diabetes Care. Available at: https://doi.org/10.2337/dc10-S062

Berger, M., Coppers, H.J., Hegner, H., Jorgens, V. dan Berchtold, P. (1982) 'Absorption Kinetics and Biologic Effects of Subcutaneously Injected Insulin Preparations', Diabetes Care, 5(2), pp. 77–91. Available at: http://diabetesjournals.org/care/article-pdf/5/2/77/495543/5-2-77.pdf.

Bitton, G., Rom, V., Hadelsberg, U., Raz, I., Cengiz, E., Weinzimer, S. and Tamborlane, W. v. (2019) 'Effect of Injection Site Cooling and Warming on Insulin Glargine Pharmacokinetics and Pharmacodynamics', Journal of Diabetes Science and Technology, 13(6), pp. 1123–1128. Available at: https://doi.org/10.1177/1932296819842151.

Casey, D.P., Ueda, K., Wegman-Points, L. and Pierce, G.L. (2017) 'Muscle contraction induced arterial shear stress increases endothelial nitric oxide synthase phosphorylation in humans', American Journal of Physiology-Heart and Circulatory Physiology, 313, pp. 854–859. Available at: https://doi.org/10.1152/ajpheart.00282.2017.-We.

Chavhan, S.P. and Chandrachood, M. v. (2020) 'Correlation of body mass index with biceps and triceps skin fold thickness', International Journal Of Community Medicine And Public Health, 7(4), p. 1475. Available at: https://doi.org/10.18203/2394-6040.ijcmph20201459.

Chun, J., Strong, J. and Urquhart, S. (2019) 'Insulin initiation and titration in patients with type 2 diabetes', Diabetes Spectrum, 32(2), pp. 104–111. Available at: https://doi.org/10.2337/ds18-0005.

Clauson, P.G. and Linde, B. (1995) 'Absorption of Rapid-Acting Insulin in Obese and Nonobese NIDDM Patients', Diabetes Care, 18(7), pp. 986–991. Available at: http://diabetesjournals.org/care/article-pdf/18/7/986/444140/18-7-986.pdf.

Dwimartutie, N., Setiati, S. and Oemardi, M. (2009) 'The Correlation Between Body Fat Distribution and Insulin Resistance in Elderly', Acta Medica Indonesiana, 42(2), pp. 66–73.

Eaton-Evans, J. (2012) 'Nutritional Assessment: Anthropometry', in Encyclopedia of Human Nutrition. Elsevier Inc., pp. 227–232. Available at: https://doi.org/10.1016/B978-0-12-375083-9.00197-5.

Förstermann, U. dan Münzel, T. (2006) 'Endothelial nitric oxide synthase in vascular disease: From marvel to menace', Circulation, pp. 1708–1714. Available at: https://doi.org/10.1161/CIRCULATIONAHA.105.602532.

Gagnon-Auger, M., du Souich, P., Baillargeon, J.P., Martin, E., Brassard, P., Ménard, J. and Ardilouze, J.L. (2010) 'Dose-dependent delay of the hypoglycemic effect of short-acting insulin analogs in obese subjects with type 2 diabetes: A pharmacokinetic and pharmacodynamic study', Diabetes Care, 33(12), pp. 2502–2507. Available at: https://doi.org/10.2337/dc10-1126.

Gradel, A.K.J., Porsgaard, T., Brockhoff, P.B., Seested, T., Lykkesfeldt, J. and Refsgaard, H.H.F. (2019) 'Delayed insulin absorption correlates with alterations in subcutaneous depot kinetics in rats with diet-induced obesity', Obesity Science and Practice, 5(3), pp. 281–288. Available at: https://doi.org/10.1002/osp4.326.

Gradel, A.K.J., Porsgaard, T., Lykkesfeldt, J., Seested, T., Gram-Nielsen, S., Kristensen, N.R. and Refsgaard, H.H.F. (2018) 'Factors Affecting the Absorption of Subcutaneously Administered Insulin: Effect on Variability', Journal of Diabetes Research. Hindawi Limited. Available at: https://doi.org/10.1155/2018/1205121.

Heinonen, I., Bucci, M., Kemppainen, J., Knuuti, J., Nuutila, P., Boushel, R. dan Kalliokoski, K.K. (2012) 'Regulation of subcutaneous adipose tissue blood flow during exercise in humans', Journal of Applied Physiology, 112, pp. 1059–1063. Available at: https://doi.org/10.1152/japplphysiol.00732.2011.-Regula.

Hildebrandt, P.R. and Vaag, A.A. (1993) 'Local Skin-Fold Thickness as a Clinical Predictor of Depot Size During Basal Rate Infusion of Insulin', Diabetes Care, 16(1), pp. 1–3.

International Diabetes Federation, 2019. IDF Diabetes Atlas, 9th ed.

Kellogg, Dean L, Zhao, J.L., Wu, Y. dan Kellogg, D L (2008) 'Endothelial nitric oxide synthase control mechanisms in the cutaneous vasculature of humans in vivo', American Journal of Physiology-Heart and Circulatory Physiology, 295, pp. 123–129. Available at: https://doi.org/10.1152/ajpheart.00082.2008.-Nitric

Kellogg, D.L., Zhao, J.L. dan Wu, Y. (2008) 'Neuronal nitric oxide synthase control mechanisms in the cutaneous vasculature of humans in vivo', Journal of Physiology, 586(3), pp. 847–857. Available at: https://doi.org/10.1113/jphysiol.2007.144642.

Kesavadev, J., Balakrishnan, S., Ahammed, S. and Jothydev, S. (2013) 'Reduction of Glycosylated Hemoglobin Following 6 Months of Continuous Subcutaneous Insulin Infusion in an Indian Population with Type 2 Diabetes', Diabetes Technology & Therapeutics, 11(8), pp. 517–521. Available at: https://doi.org/10.1089=dia.2008.0128.

Khan, M.A.B., Hashim, M.J., King, J.K., Govender, R.D., Mustafa, H. and Kaabi, J. al (2020) 'Epidemiology of Type 2 diabetes - Global burden of disease and forecasted trends', Journal of Epidemiology and Global Health, 10(1), pp. 107–111. Available at: https://doi.org/10.2991/JEGH.K.191028.001

Khera, A., Vega, G.L., Das, S.R., Ayers, C., McGuire, D.K., Grundy, S.M. and de Lemos, J.A. (2009) 'Sex differences in the relationship between c-reactive protein and body fat', Journal of Clinical Endocrinology and Metabolism, 94(9), pp. 3251–3258. Available at: https://doi.org/10.1210/jc.2008-2406.

Morello, C. (2011) 'Pharmacokinetics and pharmacodynamics of insulin analogs in special populations with type 2 diabetes mellitus', International Journal of General Medicine, p. 827. Available at: https://doi.org/10.2147/ijgm.s26889.

Mudaliar, S., Mohideen, P., Deutsch, R., Ciaraldi, T.P., Armstrong, D., Kim, B.O., Sha, X. and Henry, R.R. (2002) 'Intravenous Glargine and Regular Insulin Have Similar Effects on Endogenous Glucose Output and Peripheral Activation/Deactivation Kinetic Profiles', Diabetes Care, 25(9), pp. 1597–1602. Available at: http://diabetesjournals.org/care/article-pdf/25/9/1597/590087/dc0902001597.pdf.

Nguyen, H.P., Lin, F., Yi, D., Xie, Y., Dinh, J., Xue, P. and Sul, H.S. (2021) 'Aging-dependent regulatory cells emerge in subcutaneous fat to inhibit adipogenesis', Developmental Cell, 56(10), pp. 1437-1451.e3. Available at: https://doi.org/10.1016/j.devcel.2021.03.026.

Nourizadeh-Sedaghati, A., Herbin, M., Lukas-Croisier, C., Novella, J.L. and Delemer, B. (2016) 'Study of insulin requirement modeling in hospitalized elderly patients with type 2 diabetes at a late stage of stepwise escalation therapy', Diabetes Technology and Therapeutics, 18(5), pp. 308–315. Available at: https://doi.org/10.1089/dia.2015.0044.

Pausova, Z. (2014) 'Visceral Fat and Hypertension: Sex Differences', in Nutrition in the Prevention and Treatment of Abdominal Obesity. Elsevier Inc., pp. 99–111. Available at: https://doi.org/10.1016/B978-0-12-407869-7.00009-X.

Reznik, Y., Cohen, O., Aronson, R., Conget, I., Runzis, S., Castaneda, J. and Lee, S.W. (2014) 'Insulin pump treatment compared with multiple daily injections for treatment of type 2 diabetes (OpT2mise): A randomised open-label controlled trial', The Lancet, 384(9950), pp. 1265–1272. Available at: https://doi.org/10.1016/S0140-6736(14)61037-0.

Selcuk, A., Bulucu, F., Kalafat, F., Cakar, M., Demirbas, S., Karaman, M., Ay, S.A., Saglam, K., Balta, S., Demirkol, S. and Arslan, E. (2013) 'Skinfold Thickness as a Predictor of Arterial Stiffness: Obesity and Fatness Linked to Higher Stiffness Measurements in Hypertensive Patients', Clinical and Experimental Hypertension, 35(6), pp. 459–464. Available at: https://doi.org/10.3109/10641963.2012.746357.

Sun, H., Saeedi, P., Karuranga, S., Pinkepank, M., Ogurtsova, K., Duncan, B.B., Stein, C., Basit, A., Chan, J.C.N., Mbanya, J.C., Pavkov, M.E., Ramachandaran, A., Wild, S.H., James, S., Herman, W.H., Zhang, P., Bommer, C., Kuo, S., Boyko, E.J. and Magliano, D.J. (2022) 'IDF Diabetes Atlas: Global, regional and country-level diabetes prevalence estimates for 2021 and projections for 2045', Diabetes Research and Clinical Practice, 183. Available at: https://doi.org/10.1016/j.diabres.2021.109119.

Tramunt, B., Smati, S., Grandgeorge, N., Lenfant, F., Arnal, J.F., Montagner, A. and Gourdy, P. (2020) 'Sex differences in metabolic regulation and diabetes susceptibility', Diabetologia. Springer, pp. 453–461. Available at: https://doi.org/10.1007/s00125-019-05040-3.

Wang, J., Thornton, J.C., Kolesnik, S. and Pierson, R.N. (2006) Anthropometry in Body Composition An Overview.